Quality Assurance in Laser Sintering

Development of an SLS Process Chain Suitable for Mass Manufacturing

Although the virtually unrestricted geometric complexity of the parts they produce have made additive manufacturing technologies an efficient tool for the rapid development and manufacture of products, the parts they produce have not been satisfactorily reproducible to quality that ensures manufactured properties are identical.

A quality management system integrated throughout the additive manufacturing process chain is being developed for selective laser sintering (SLS) in the AGENT-3D research project QualiPro. It is intended to deliver reproducible part quality and thus be suitable for mass manufacturing.

The Fraunhofer IFF's key activity in its subproject is the development of the specifications QM data management for laser sintering of plastic powder and, based on this, the definition of QM criteria for plastic laser sintering systems. Algorithms are being developed for this, which identify causal relationships and correlations between the parameters of the base material, manufacturing process, final product and part quality. Process and part quality assessment is intended to deliver conclusions about the input parameters set. e.g. powder quality, system settings, laser output, scan rate, environmental conditions, process indicators (e.g. powder layer quality, moving axes, process radiation, temperature) and part characteristics (e.g. mechanical properties, density, porosity, dimensional tolerance, surface roughness).

The recorded data will ultimately be collected in a single part certificate and verify the complete system's process capability (reproducibility) on the demonstration part.

The measurement chains needed for data acquisition are being developed. Suitable sensor principles and other constraints relevant to data acquisition, e.g. form and dimensional tolerance, finish quality, and part position, are being identified. Real build process data ascertained in tests with simulated process disturbances (defect provocation) will be compared to develop the measurement algorithms and to evaluate critical interfaces for laser sintering.

Measurable Success Criteria

The following quantifiable success criteria will be used to verify the achievement of the project objectives on suitable test specimen geometries:

- increasing part quality (lowering the reject rate) in selective laser sintering at least 20% by recording data in and after the manufacturing process,
- increasing additive manufacturing process reliability for SLS 20-25% by integrating testing and inspection based on 3D scan data (process monitoring), and
- cutting costs 20-30% by improving process understanding (reproducibly linking recorded process data with part quality.

Applied Test Specimen Geometry Quality Assurance

Current additive manufacturing technologies are so specific that a standardized test specimen geometry does not exist yet. A geometry with a shape and size (100 x 50 x 20 mm³) suited for all relevant analyses and tests (Fig. 1) was defined for the tests.

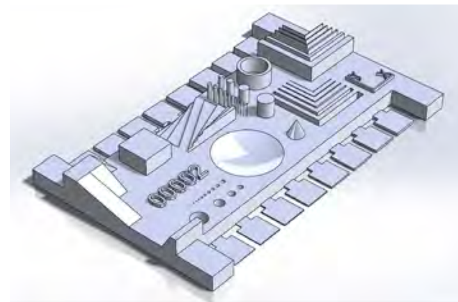

Figure 1: Selected test specimen geometry

It consists of different geometric elements positioned on different planes. Data on different geometric elements (cylinders, bores, cuboid block elements, etc.) are recorded for the QM system. Cylinders are positioned at 0°-, 45°- and 90° angles to the reference plane. Bores are in xy-, xz- and yz planes. This configuration makes it possible to identify process disturbances.

Cuboid block elements of varying thicknesses are used to measure achievable layer thicknesses and minimum wall thicknesses. Dimensional accuracy (deformation and horizontal displacement) is determined by measuring the outer and bore diameters in every dimension and angle variations in the XY plane and the z-direction. The tests are based on VDI Guideline 3405, Sheet 1.

Benchmark Studies for Process Parameter Optimization

Different parameters' influence on test specimen quality has been studied in extensive benchmark studies to assess quality features. Test plans were drafted following methods of statistical test planning (e.g. factorial test plan based on Box-Behnken designs). Ten inspection parameters run through an inspection plan using standard-screening were defined for the tests. Afterward, an analysis of variance (including an estimation of the independent variables' effects with a Pareto chart) was performed, a regression analysis was performed, and the dependent variables were optimized.

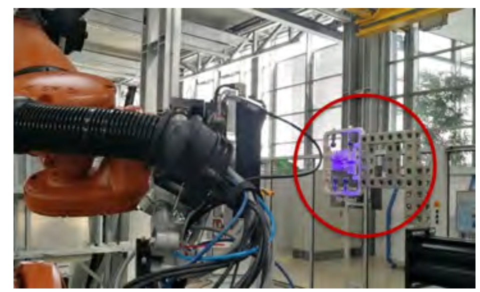

Figure 2: Scanning with the Gocator 3110 3D snapshot sensor

Structured-light 3D sensors, light section sensor, laser tracers and CMMs were the scanning systems used to benchmark automated 3D inspection. Other tests for these systems are currently in progress (Fig. 2) to ensure the desired statistical certainty (probability) and the confidence interval for the parameter values. The entire measurement process that captures the point clouds takes two minutes (total time to generate the scan). The Gocator has an accuracy of 0.1 mm.

Literature:

[1] Schmidt, M.: Selektives Lasersintern (SLS) mit Kunststoffen. Technologie, Prozesse, Werkstoffe. Munich. Hanser Verlag 2015.

[2] VDI 3405, Blatt 1: Additive manufacturing processes - Laser sintering of polymer parts - Quality control. Berlin. Beuth Verlag 2019.

[3] Kleppmann, W.: Versuchsplanung: Produkte und Prozesse optimieren. Hanser Fachbuchverlag 2016.

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Bundesministerium für Bildung und Forschung

Fraunhofer Institute for Factory Operation and Automation IFF
Dr.-Ing. Uwe Klaeger
☎: +49 391 4090-809
✉: uwe.klaeger@iff.fraunhofer.de
www.iff.fraunhofer.de